Indoor Air Quality and Acute Lower Respiratory Infection in Indian Urban Slums

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The present prospective study was conducted at two urban slums of Delhi, Kusumpur Pahari and Kathputly Colony, in the peak winter season from November 1994 through February 1995. We studied 642 infants to determine the incidence of acute lower respiratory infection (ALRI) and its relationship to indoor air pollution due to fuel used for cooking (wood or kerosene). In Kusumpur Pahari, there were 317 children (142 wood and 175 kerosene), including 64 controls and 78 cases of ALRI in the wood fuel group and 81 controls and 94 ALRI cases in the kerosene group ($p>0.05$). Out of 316 children in Kathputly Colony (174 wood and 142 kerosene), there were 33 and 45 ALRI cases in the wood and kerosene groups, respectively ($p<0.05$). Controls were children without ALRI and were used as controls in different groups. The demographic data and risk factors, namely, nutritional and immunization status, were comparable in ALRI cases and controls in both study areas. Pneumonia was the most common ailment in all the groups. Bronchiolitis was reported in 22.5% of the wood group and 27.1% of the kerosene group in Kathputly Colony versus 13.7% in the wood group and 12.1% in the kerosene group in Kusumpur Colony. Only one case of croup was reported from Kusumpur Pahari among wood users. The duration of illness was longer in the Kusumpur Pahari due to poor compliance, feeding, and child rearing habits. In conclusion, a higher incidence of ALRI was reported in kerosene users in Kathputly Colony, a high pollution area; however, the reasons for the differences observed need further elucidation. *Key words*: acute respiratory tract infection, ALRI , ARI, fuel, incidence, indoor air quality, infants, kerosene, urban slums, wood. *Environ Health Perspect* 106:291–297 (1998). [Online 7 April 1998]
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Acute respiratory infections (ARI), together with malnutrition and diarrheal disease, constitute the most common cause of illness and death among children under 5 years of age in developing countries. The incidence of ARI is considerably higher in developing countries; 15–20% of children under 5 years of age suffer from pneumonia every year. Of these, ARI accounts for 15–30% of childhood deaths, with a mortality ranging from 3.2 to 13.8 deaths/1,000 children. On an average, a child in an urban area suffers from five to eight episodes, whereas in rural areas, three to five episodes of ARI occur per year (*1*).

Acute lower respiratory infection (ALRI) constitutes a complex and heterogeneous group of illnesses. Bronchiolitis, acute laryngitis, and pneumonia are primarily responsible for the majority of ALRI-related deaths among children. A community-based epidemiological study conducted in Beijing, China, showed that the highest incidence of ALRI occurred in children under 1 year of age: 4.2 episodes per child per year in infants compared to 2.1 episodes per child per year among children 4–5 years old (*2*). Board on Science and Technology for International Development (BOSTID) researchers also found that the pattern of age-specific rates of ALRI has a striking pattern of decreasing incidence rates with increasing years of age (*3*).

Host-, environmental-, and socioculturral-related variables may act independently or in concert with other variables to influence the incidence and severity of ALRI. Therefore, it is important to understand the relative contribution of various risk factors. Settings such as slums with overcrowding and inadequate water supplies and sanitation systems predispose to poor personal hygiene, which can further enhance transmission. These risk factors also predispose children to frequent and recurrent infections that impair tissue recovery and can lead to more severe disease.

Biomass smoke is an important cause of indoor pollution and is one of the predisposing factors in ARI (*4–6*), but its importance in relation to other risk factors in young infants is not clearly established (*7*). The highest exposures are probably experienced by women, infants, and young children. Exposure to pollution from wood burning stoves for indoor heating is associated with severe respiratory symptoms and mortality (*6,8*). Women and children in urban slums are additionally exposed to pollution from industrial and vehicular sources because slums are commonly located near factories and highways. Thus, it would appear that the urban slum community bears the higher air pollution exposure burden in developing countries because of the presence of both indoor and outdoor sources. In rural areas, estimation of the exposure from biomass combustion has been attempted (*9*), but the information for urban areas is meager (*10*). It has been postulated that switching from lower to higher quality fuels, i.e., moving up the energy ladder, generally leads to substantially lower emissions of health-damaging pollutants in urban areas.

Widespread case management would be expensive and would not be an answer in the long term because mild ARI can progress from moderate to severe phases and death often in only 2–3 days (*4*). Hence, if risk factors predisposing to more severe disease after initial infection can be identified and prevented, much of the mortality and morbidity burden due to ARI can possibly be prevented in developing countries. Therefore, data on the incidence and causes of ARI need to be generated. Although some data on ARI are available, most information has come from hospitals and outpatient clinics only. Looking at the magnitude of the problem in the context of child survival and the fact that high exposure to indoor air pollution is experienced by infants, the most vulnerable group with highest mortality, this community-based prospective preliminary study was designed to determine the incidence of ALRI in the peak winter season in two slums of Delhi, to determine if there is any relationship between indoor pollution and ALRI in children, and to identify the risk factors responsible for increases in the severity of ALRI.

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Materials and Methods

There are more than 1,000 slum clusters in Delhi, and more than 1.5 million people reside in these slums. Out of 50 slums surveyed, 2 slums were selected. Surveys were used to gather information on the total number of households, the number of households using wood or kerosene, distance of the slum from an industrial complex, major roads, the nearest air quality monitoring station, and the type of house. The study area included two large urban slums, Kathputly Colony (high pollution area), and Kusumpur Pahari (low pollution area), which are situated at the west and south edge of Delhi, with 4,500 and 5,000 households, respectively. In Kusumpur Pahari, about 3,500 and 1,500 households exclusively used wood and kerosene, respectively. In Kathputly Colony, 1,523 and 2,828 households exclusively used wood and kerosene, respectively. Out of 545 and 530 infants in Kusumpur Pahari and Kathputly Colony, respectively, 320 infants under 1 year of age at the time of enrollment were selected in a stratified random manner from each slum. The stratification criteria included location of cooking, employment status of the mother, and households with more than one sleeping room. Households in which cooking was done outdoors, there was more than one sleeping room, and the mother was employed were not included in the study. In both slums, 160 houses with infants were chosen each in the wood and kerosene categories.

The study group consisted of 642 infants: 316 in Kathputly Colony and 326 in Kusumpur Pahari. The study protocol was explained to all the parents, and their consent was obtained. These children were further divided into two groups depending upon the fuel (kerosene or wood) used for cooking. This prospective cohort study was designed to collect data on symptoms that occurred in the winter (1 November 1994 through 28 February 1995).

Two doctors and 12 health workers with previous experience of working in the community collected health-related data. All of them were trained to differentiate pneumonia from no pneumonia using NARICOP [National Acute Respiratory Infection Control Program (*1*)] and World Health Organization [WHO (*11–13*)] criteria. Each health worker was assigned 55–56 infants, and they visited these houses twice a week to collect information on ARI. Parents of all infants were interviewed by health workers during the visits using a self explanatory structured questionnaire. In addition to demographic data, socioeconomic status, detailed history to elicit possible risk factors such as immunization, nutritional status, and past history of any episode of ALRI (namely, pneumonia, bronchiolitis, and wheezing) was elicited. Simultaneously, another group of workers from Tata Energy Research Institute collected exposure-related data including basic household information, environmental factors such as source of heat, cooking, time budget (activity pattern of people in relation to environment), microenvironment, and exposure to other potential sources of indoor pollutants such as smoking by family members. In a subsample of 80 houses, the daily exposure to respirable suspended particulate (RSP) was estimated. Area sampling was done in all microenvironments using low flow pumps (1.9 l/min). A Cyclone (SKC Inc.) with cut-off efficiency of 50% at 5 μm particle diameter was attached to these pumps. Further details of the procedure followed for the estimation of RSP have been published elsewhere (*14*).

Age was recorded in completed weeks, as given by the mother. All children were weighed accurately every month. Nutritional status was graded using Gomez classification with reference to National Center for Health Statistics (NCHS) standards for weight for age (normal, >90%; mild malnutrition, 90–76%; moderate malnutrition, 75–60%; severe malnutrition, <60%).

ALRI case children were those with a diagnosis of pneumonia, bronchiolitis, croup, or bronchial asthma as described by NARICOP and WHO criteria. ALRI was defined clinically as the presence of a cough of less than 4-weeks duration with one or more of the following symptoms: fever, rapid breathing, noisy breathing, running nose, sore throat, and otorrhoea (for defining acute otitis media, the duration was reduced to 2 weeks). The WHO clinical classification for ARI was used for defining severity of ALRI cases:

- Pneumonia when a patient had a rapid breathing rate (60 breaths/min or more in children 0–2 months of age; 50 breaths/min or more in the children aged 2–12 months; and 40 breaths/min or more in children aged 13–60 months, but with no chest indrawing
- Severe pneumonia when a patient had a rapid breathing rate and chest indrawing
- Very severe illness when, in addition to severe pneumonia, the child had one or more of the following: inability to drink, convulsions, abnormal sleepiness or difficulty in waking, stridor when calm, wheezing, and severe undernutrition
- All children under the age of 2 months with features suggestive of pneumonia or systemic infection were presumed to be very severely ill.

Children with no symptoms or presenting with cough without chest indrawing or rapid breathing were defined as having no ALRI and were used as controls. Bronchiolitis was defined as having a respiratory rate as defined for pneumonia, and wheeze with or without respiratory distress on clinical examination. Laryngotracheo-bronchitis or croup was defined in infants with brassy cough, inspiratory stridor, hoarseness, and/or respiratory distress. Diagnosis of bronchial asthma was made if the infant suffered from more than two episodes of wheezing in the year.

Health workers identified children with rapid breathing with or without features of severe pneumonia or very severe illness, and the diagnosis of ALRI was confirmed by a study physician. After detailed clinical examination, a specific diagnosis such as pneumonia, bronchiolitis, croup, or bronchial asthma was made, and the illness was classified as pneumonia, severe pneumonia, or very severe illness.

To record different episodes of ALRI, the following working definition was adopted: if a child suffering from ALRI was reported to be completely free of signs and symptoms of ALRI for at least 7 days and then contracted another ALRI attack, it was considered a new or fresh episode of ALRI.

Mild upper respiratory infection was treated by palliative treatment or home remedies but no antibiotics. All infants over the age of 2 months diagnosed with ALRI were treated with co-trimoxazole tablets or syrup (trimethoprim 8 mg/kg/day plus sulfamethoxazole 40 mg/kg/day) every 12 hours, ampicillin (50 mg/kg/day) in three divided doses, cephalexin 30 mg/kg/day, or erythromycin orally for 5–7 days as recommended by NARICOP as the initial antibiotic for ambulatory treatment, in addition to necessary supportive care. Young infants under 2 months of age and children with severe pneumonia and very severe illness were referred to hospitals. Only in cases in which parents were reluctant to admit children to hospitals, oral antibiotics were administered at home under the supervision of the study physician. Indicators of good response to antibiotics were subsiding fever if initially present, lesser chest indrawing, decreasing respiratory rate, and improvement in food and liquid intake. All cases were reassessed after 48 hr, but earlier if breathing became difficult, the child was not able to drink, or symptoms worsened.

Infants who were absent from the study area for 2 consecutive weeks or more were not included for the analysis. Cases not containing relevant details were also omitted from the final analysis.

The incidence rate was calculated by dividing the total number of new cases of ALRI during the period of observation by the total number of child weeks at risk

during that period. The denominator was calculated by subtracting number of weeks with ALRI from each child's total time under observation. Statistical analyses of the incidence of symptoms of ALRI in infants were compared in both slums in both the fuel groups to determine relationship, if any, between indoor pollution and ALRI. Statistical analyses of the association between ALRI and potential risk factors were performed with the use of a stratified analysis technique. Additional software used for management and analysis of the data included dBASE III Plus and Statistical Package for Social Sciences Software (SPSS/PC+). Chi-square and Fisher exact tests were used as tests of significance.

Results

A total of 642 children were enrolled in the study, out of which 9 were excluded because their families were using both wood and kerosene stoves. In Kusumpur Pahari, 3 infants in the wood group and 2 in the kerosene group were lost to follow-up: 3 in the third week and 1 each in the eighth and ninth study weeks. In Kathputly Colony, a total of 18 infants (12 wood and 6 kerosene) were lost to follow-up: 10 infants in third week, 3 in the fourth week, 2 each in the sixth and eighth weeks, and 1 in the tenth study week. Hence, 633 children were included in the analysis. Out of the 317 (142 wood and 175 kerosene) children in Kusumpur Pahari, there were 64 controls (no ALRI) and 78 ALRI cases in the wood group and 81 controls and 94 ALRI cases in the kerosene group. Out of 316 (174 wood and 142 kerosene) children in Kathputly Colony, there were 33 and 45 ALRI cases in the wood and kerosene groups, respectively. The overall incidence rate of ALRI in the study population was 3.9 episodes per 100 child weeks at risk. In Kusumpur Pahari, incidence of ALRI was 6.3 and 5.9 episodes per 100 child weeks at risk in the wood and kerosene groups, respectively. In Kathputly colony, the incidence rate of ALRI was 1.6 and 2.9 episodes per 100 child weeks at risk in the wood and kerosene groups, respectively.

Age and sex distribution of ALRI cases and controls was comparable in both fuel groups and study slums (Table 1 and 2). Table 3 shows demographic data of wood and kerosene groups in both slums. There were 78 (54.9%) and 94 (53.7%) ALRI cases in the wood and kerosene groups in Kusumpur Pahari, respectively ($p>0.05$). In Kathputly Colony, there were 33 (19%) ALRI cases in the wood group and 45 (31.7%) ALRI cases in the kerosene group ($p<0.05$).

On analyzing parental education of fathers in Kusumpur Pahari (Table 3), about 49.3% of fathers from the wood group were illiterate, but out of those who were literate, 26.1% had passed middle class and 18.3% had qualified up to secondary level. The percentage of secondary-level educated fathers among kerosene-user families was even higher, i.e., 36% for middle class and 23.4% for secondary level. On the contrary, the majority of mothers were illiterate (88% in the wood group vs. 74.3% in the kerosene group; $p<0.002$). The majority of the fathers were self-employed and mothers were housewives in both fuel groups ($p>0.05$). Families included more than four members in both fuel groups ($p<0.05$). In Kathputly Colony, more than 60% of fathers were illiterate in both fuel groups ($p>0.05$). There were more

Table 1. Age and sex distribution of index children in Kusumpur Pahar

	Wood			Kerosene		
Index child	Control ($n=64$)	ALRI ($n=78$)	Total ($n=142$)	Control ($n=81$)	ALRI ($n=94$)	Total ($n=175$)
Age						
1–8 weeks	15 (23.4)	14 (17.9)	29 (20.4)	13 (16.0)	17 (20.2)	30 (17.1)
9 weeks to 1 year	49 (76.6)	64 (82.1)	113 (79.6)	68 (84.0)	77 (79.8)	145 (82.9)
Sex						
Male	29 (45.3)	45 (57.7)	74 (52.1)	47 (58.0)	45 (47.9)	92 (52.6)
Female	35 (54.7)	33 (42.3)	68 (47.9)	34 (42.0)	49 (52.1)	83 (47.4)

ALRI, acute respiratory tract infection. Values in parentheses denote percentages.

Table 2. Age and sex distribution of index children in Kathputly Colony

	Wood			Kerosene		
Index child	Control ($n=141$)	ALRI ($n=33$)	Total ($n=174$)	Control ($n=97$)	ALRI ($n=45$)	Total ($n=142$)
Age						
1–8 weeks	24 (16.7)	7 (21.2)	31 (17.8)	14 (14.4)	10 (22.2)	24 (16.9)
9 weeks–1 year	117 (83.0)	26 (78.8)	143 (82.2)	83 (85.6)	35 (77.8)	118 (83.1)
Sex						
Male	66 (46.8)	11 (33.3)	77 (44.2)	44 (45.4)	20 (44.4)	64 (45.1)
Female	75 (53.2)	22 (66.7)	97 (55.8)	53 (54.6)	25 (55.6)	78 (54.9)

ALRI, acute respiratory tract infection. Values in parentheses denote percentages.

Table 3. Comparison of demographic data of wood and kerosene groups in both Kusumpur Pahari and Kathputly Colony

	Kusumpur Pahari			Kathputly Colony		
	Wood ($n=142$)	Kerosene ($n=175$)	p-Value	Wood ($n=174$)	Kerosene ($n=142$)	p-Value
Father's education						
Illiterate	70 (49.3)	63 (36.0)	NS	107 (61.5)	87 (61.3)	NS
Primary	7 (4.9)	3 (1.7)		13 (7.5)	15 (10.6)	
Middle	37 (26.1)	63 (36.0)		45 (25.9)	31 (21.8)	
Secondary	26 (18.3)	41 (23.4)		9 (5.1)	9 (6.3)	
Higher secondary	2 (1.4)	4 (2.3)		–	–	
Graduate	–	1 (0.6)		–	–	
Mother's education						
Illiterate	125 (88.0)	130 (74.3)	0.002	168 (96.6)	123 (86.6)	0.001
Primary	17 (12.0)	45 (25.7)		6 (3.4)	19 (13.4)	
Father's occupation						
Wage laborer	41 (28.9)	40 (22.9)	NS	12 (6.9)	24 (16.9)	0.002
Self-employed	99 (69.7)	135 (77.1)		162 (93.1)	115 (81.0)	
Unemployed	2 (1.4)	–			3 (2.1)	
Mother's occupation						
Housewife	109 (76.8)	146 (83.4)	NS	161 (92.5)	103 (72.5)	0.001
Self-employed	33 (23.2)	29 (16.6)		13 (7.6)	39 (7.5)	
Family size						
1–4 members	58 (40.8)	96 (54.9)	0.04	65 (37.4)	56 (39.4)	NS
>4 members	84 (59.1)	79 (45.1)		109 (62.6)	86 (60.6)	
Siblings[a]						
≤2 years	22	24	NS	28	19	NS
>3 years	265	255		357	273	

NS, not significant. Values in parentheses denote percentages.
[a]Difference in age between the index child and the closest older sibling.

illiterate mothers (96.6%) in the wood group compared to 86.6% in the kerosene group ($p<0.001$). The majority of the fathers were self-employed and the mothers were housewives ($p<0.002$). In more than 60% of the families, there were more than four family members in both fuel groups and in both slums, and the age gap between the index child and the closest older sibling appeared to be more than 2 years (Table 3).

In Kusumpur Pahari, it was observed that nearly 50% of the fathers in the wood group were illiterate (Table 4), and the majority of mothers in both wood and kerosene groups were illiterate (88% vs. 74.3%). The majority of the fathers were self-employed and the mothers were housewives in both fuel groups. However, the number of self-employed mothers was less in the kerosene group than in the wood group ($p<0.02$).

Demographic data of Kathputly Colony (Table 5) showed that approximately 60% of fathers and 90% of mothers were illiterate. There was no statistically significant difference between ALRI cases and controls in both fuel groups as far as education of fathers and mothers was concerned, although there were more illiterate mothers in the wood group (96.6%) than in the kerosene group (86.6%). About 81% and 93% of the fathers were self-employed in the kerosene and wood groups, respectively.

Regarding smoking habits, 67% of the fathers smoked (71% of the wood group and 63% of the kerosene group; ($p>0.05$); there were no interslum differences in smoking habits. Among mothers, only 8% smoked, and there was no difference between the fuel groups. However, the interslum differences for mother's smoking habits were significant (5% in Kathputly Colony vs. 10% in Kusumpur Pahari). The average period of smoking was 9 years for mothers and 13 years for fathers.

The nutritional status and immunization status were comparable in controls and ALRI cases in both fuel groups and study slums respectively (Tables 6 and 7). A similar number of children were malnourished in both study slums; however, in Kusumpur Pahari, the number of severely malnourished children was significantly greater (25.8%) in the wood group compared to the kerosene group (10.7%; $p<0.006$) (Table 7). In Kathputly Colony, there were more unimmunized children in the wood group. Measles immunization status was comparable in both groups in these study slums (Table 6).

Table 8 depicts the distribution of children suffering from ALRI according to the number of episodes during the study period. The total number of episodes of ALRI observed included 102 in the wood group and 116 in the kerosene group in Kusumpur Pahari and 40 in the wood group and 59 in the kerosene group in Kathputly Colony. At Kusumpur Pahari, 54% of the children in the wood group suffered from ALRI during the study period (73% with one episode and 23% with two episodes). A similar distribution was observed in the kerosene group in Kusumpur Pahari. There were three children with three episodes of ALRI in the wood group compared to one case in kerosene

Table 4. Comparison of demographic data of controls and acute lower respiratory infection (ALRI) cases in wood and kerosene groups in Kusumpur Pahari

	Wood				Kerosene			
	Control ($n=64$)	ALRI ($n=78$)	Total ($n=142$)	p-Value	Control ($n=81$)	ALRI ($n=94$)	Total ($n=175$)	p-Value
Father's education								
Illiterate	34 (53.1)	36 (46.2)	70 (49.3)	NS	32 (39.5)	31 (33.9)	63 (36)	NS
Primary	1 (1.5)	6 (7.7)	7 (4.9)		1 (1.2)	2 (2.1)	3 (1.7)	
Middle	19 (29.7)	18 (23.1)	37 (26.1)		26 (32.1)	37 (39.4	63 (36.0)	
Secondary	10 (15.6)	16 (20.5)	26 (18.3)		20 (25.7)	21 (22.3)	41 (23.4)	
Higher secondary	–	2 (2.5)	2 (1.4)		2 (2.5)	2 (2.1)	4 (2.3)	
Graduate	–	–	–		–	1 (1)	1 (0.6)	
Mother's education								
Illiterate	57 (89)	68 (87.2)	125 (88.0)	NS	60 (74.1)	70 (74.5)	130 (74.3)	NS
Primary	7 (11)	10 (12.8)	17 (12.0)		21 (25.9)	24 (25.5)	45 (25.7)	
Father's occupation								
Wage laborer	22 (34.4)	19 (24.3)	41 (28.9)	NS	19 (23.5)	21 (22.3)	40 (22.9)	NS
Self-employed	41 (64.1)	58 (74.4)	99 (69.7)		62 (76.5)	73 (77.7)	135 (77.1)	
Unemployed	1 (1.6)	1 (1.3)	2 (1.4)					
Mother's occupation								
Housewife	50 (78.1)	59 (75.6)	109 (76.8)	NS	62 (76.5)	84 (89.4)	146 (83.4)	0.02
Self-employed	14 (21.9)	19 (24.4)	33 (23.2)		19 (23.5)	10 (10.6)	29 (16.6)	
Family size								
1–4 members	30 (47)	28 (35.9)	58 (40.8)	NS	47 (58)	49 (52)	96 (54.9)	NS
>4 members	34 (53)	50 (64.1)	84 (59.2)		34 (42)	45 (48)	79 (45.1)	
Siblings[a]								
≥2 years	9	13	22	NS	10	14	24	NS
>3 years	109	156	265		110	145	255	

NS, not significant. Values in parentheses denote percentages.
[a]Difference in age between the index child and the closest older sibling.

Table 5. Comparison of demographic data of controls and acute lower respiratory infection (ALRI) cases in wood and kerosene groups in Kathputly Colony

	Wood				Kerosene			
	Control ($n=141$)	ALRI ($n=33$)	Total ($n=174$)	p-Value	Control ($n=97$)	ALRI ($n=45$)	Total ($n=142$)	p-Value
Father's education								
Illiterate	86 (61)	21 (63.6)	107 (61.5)	NS	65 (67)	22 (48.9)	87 (61.3)	NS
Primary	10 (7.1)	3 (9.1)	13 (7.5)		7 (7.2)	8 (17.8)	12 (10.6)	
Middle	38 (26.9)	7 (21.2)	45 (25.8)		20 (20.6)	11 (24.4)	31 (21.8)	
Secondary	7 (5)	2 (6.1)	9 (5.2)		5 (5.2)	4 (8.9)	9 (6.3)	
Higher secondary	–	–	–		–	–	–	
Graduate	–	–	–		–	–	–	
Mother's education								
Illiterate	138 (97.9)	30 (90.9)	168 (96.6)	0.04	83 (85.6)	40 (88.9)	123 (86.6)	NS
Primary	3 (2.1)	3 (9.1)	6 (3.4)		14 (1.40)	5 (11.1)	19 (13.4)	
Father's occupation								
Wage laborer	9 (6.4)	3 (9.1)	12 (6.9)	NS	10 (10.3)	14 (31.1)	24 (16.9)	0.00
Self-employed	132 (93.6)	30 (90.9)	162 (93.1)		85 (87.6)	30 (66.7)	115 (81)	
Unemployed	–	–	–		2 (2.1)	1 (2.2)	3 (2.1)	
Mother's occupation								
Housewife	131 (92.9)	30 (90.9)	161 (92.5)	NS	70 (72.2)	33 (73.3)	103 (72.5)	NS
Self-employed	10 (7.1)	3 (9.1)	13 (7.5)		27 (27.8)	12 (26.7)	39 (27.5)	
Family size								
1–4 members	51 (36.2)	14 (42.4)	65 (37.4)	NS	41 (42.3)	15 (33.3)	56 (39.4)	NS
>4 members	90 (63.8)	19 (57.6)	109 (62.6)		56 (57.7)	30 (66.7)	86 (60.6)	
Siblings[a]								
≤2 years	19	9	28	NS	14	3	17	NS
>3 years	294	63	357		179	94	273	

NS, not significant. Values in parentheses denote percentages.
[a]Difference in age between the index child and the closest older sibling.

Table 6. Comparison of nutritional and immunization status of controls and acute lower respiratory infection (ALRI) cases in Kusumpur Pahari and Kathputly Colony

	Kusumpur Pahari				Kathputly Colony			
	Wood		Kerosene		Wood		Kerosene	
	Control (*n* = 64)	ALRI (*n* = 78)	Control (*n* = 81)	ALRI (*n* = 94)	Control (*n* = 141)	ALRI (*n* = 33)	Control (*n* = 97)	ALRI (*n* = 45)
Nutritional status[a]								
Normal	25 (41.0)	29 (39.2)	32 (41.0)	38 (42.2)	38 (31.9)	11 (34.4)	28 (30.4)	20 (44.4)
Mild malnutrition	11 (18.0)	14 (18.9)	25 (32.0)	29 (32.2)	47 (39.5)	10 (31.3)	38 (41.3)	17 (37.8)
Moderate malnutrition	8 (8.0)	13 (17.6)	9 (11.5)	17 (18.9)	28 (23.5)	8 (25.0)	21 (22.8)	7 (15.6)
Severe malnutrition	17 (27.9)	18 (24.3)	12 (15.9)	6 (6.7)	6 (5.0)	3 (9.4)	5 (5.4)	1 (2.2)
Immunization status								
Not immunized	22 (34.4)	19 (24.4)	20 (24.7)	26 (27.7)	60 (42.6)	13 (39.4)	23 (23.7)	18 (40.0)
Partially immunized	24 (37.5)	39 (50.0)	32 (39.5)	32 (34.0)	45 (37.9)	15 (45.5)	38 (39.2)	13 (28.9)
Completely immunized	18 (28.1)	20 (25.6)	29 (35.8)	36 (38.3)	36 (25.5)	5 (15.2)	36 (37.1)	14 (31.1)
Measles immunization (Infants ≥36 weeks)								
Infants eligible	24 (37.5)	28 (35.9)	35 (45.5)	42 (54.5)	82 (58.1)	12 (36.4)	58 (59.8)	15 (33.3)
Immunized	12 (50.0)	12 (42.9)	18 (51.4)	22 (52.4)	22 (26.8)	2 (16.7)	16 (27.6)	4 (26.7)
Not immunized	12 (50.0)	16 (48.6)	17 (48.6)	20 (47.6)	58 (70.7)	10 (83.3)	42 (72.4)	11 (73.3)

Values in parentheses denote percentages. Infants with missing data were omitted from analyses.

[a]Nutritional status according to Gomez's classification: normal, >90% of the normal weight for age; mild malnutrition, 90–76% of the normal weight for age; moderate malnutrition, 75–60% of the normal weight for age; severe malnutrition, <60% of the normal weight for age.

group. The total number of episodes at Kathputly Colony was much lower in the wood group compared to the kerosene group. There were also fewer children with more than one episode of ALRI than in Kusumpur Pahari.

Pneumonia was the most common ailment in both fuel groups and study slums. However, the number of cases with bronchiolitis reported from Kathputly Colony (22.5% for wood vs. 27.1% for kerosene) was higher than that reported from Kusumpur Pahari (13.7% for wood and 12.1% for kerosene). Croup and laryngo tracheomalacia was reported in one case in each of the study slums. Few cases of bronchial asthma were incorporated as ALRI because rapid breathing was taken as one of the criteria for the diagnosis of pneumonia.

The health workers identified severity of illness in ALRI cases based on WHO criteria. ALRI case children were categorized as having pneumonia, severe pneumonia, or severe illness as per information available in the proforma. There was a strong concurrence of diagnosis made by health workers and doctor. In Kusumpur Pahari, the majority of the ALRI cases (79.4%) were pneumonia, 19.6% had severe pneumonia, and there was only one case of very severe illness. On the contrary, although the number of cases with severe pneumonia was almost the same as in Kathputly Colony, there was a significant number that were categorized as very severe illness by the health workers (Table 9).

The duration of illness of each episode of ALRI varied from 7 to 15 days. The majority of children were treated with co-trimoxazole in both areas. About 15% of infants were given the alternative drugs amoxycillin and cephalosporin. The majority of parents of infants with severe illness preferred domiciliary treatment with co-trimaxazole.

Mortality. Five infants died in Kusumpur Pahari during the study period. Two deaths occurred due to ALRI (one in each fuel group), two deaths occurred due to diarrhea, and one child died because of a convulsive disorder. Two deaths occurred in Kathputly Colony due to ALRI in the wood group and the other child died for an unknown reason.

Table 7. Comparison of nutritional status and immunization status between wood and kerosene groups in both study slums

	Kusumpur Pahari			Kathputly Colony		
	Wood (*n* = 142)	Kerosene (*n* = 175)	*p*-Value	Wood (*n* = 174)	Kerosene (*n* = 142)	*p*-Value
Nutritional status[a]						
Normal	54 (40.0)	70 (41.7)	0.006	49 (32.5)	48 (35.0)	NS
Mild malnutrition	25 (18.5)	54 (32.1)		57 (37.7)	55 (40.1)	
Moderate malnutrition	21 (15.6)	26 (15.5)		36 (23.8)	28 (20.4)	
Severe malnutrition	35 (25.8)	18 (10.7)		9 (6.0)	6 (4.4)	
Missing	7 (5.9)	7 (4.0)		23 (13.2)	5 (3.5)	
Immunization status						
Not immunized	41 (28.9)	46 (26.3)	NS	73 (42.0)	41 (28.9)	0.02
Partially immunized	63 (44.4)	64 (36.6)		60 (34.5)	51 (35.9)	
Completely immunized	38 (26.8)	65 (37.1)		41 (23.5)	50 (35.2)	
Measles immunization status (infants ≥36 weeks)						
Infants eligible	52 (40.3)	77 (59.7)	NS	94 (54.0)	73 (43.7)	NS
Immunized	24 (46.2)	40 (51.9)		24 (25.5)	20 (27.4)	
Not immunized	28 (53.8)	37 (48.1)		68 (72.3)	53 (72.6)	
Missing data	–	–		2 (2.1)	–	

NS, not significant. Values in parentheses denote percentages.

[a]Nutritional status according to Gomez's classification: normal, >90% of the normal weight for age; mild malnutrition, 90–76% of the normal weight for age; moderate malnutrition, 75–60% of the normal weight for age; severe malnutrition, <60% of the normal weight for age.

Table 8. Distribution of number of episodes of acute lower repiratory infection (ALRI) in Kusumpur Pahari and Kathputly Colony

	Kusumpur Pahari		Kathputly Colony	
	Wood	Kerosene	Wood	Kerosene
Total number of infants	142	175	174	142
Total number of episodes	102	116	40	59
Number of children with ALRI	78 (54)	94 (53)	33 (18.9)	45 (31)
Number of children with one episode	57 (73)	73 (76.7)	27 (81.8)	32 (71.1)
Number of children with two episodes	18 (23)	20 (15.2)	5 (15.2)	12 (26.7)
Number of children with three episodes	3 (4)	1 (1.1)	1 (3.0)	1 (2.2)

Values in parentheses denote percentages.

Discussion

The aim of the present study was to determine the incidence rate of ALRI in two

Table 9. Severity of illness in Kusumpur Pahari and Kathputly Colony

	Kusumpur Pahari		Kathputly Colony	
Severity of illness	Wood (n = 102)	Kerosene (n = 116)	Wood (n = 40)	Kerosene (n = 59)
Pneumonia	81 (79.4)	94 (81.0)	17 (42.5)	11 (18.6)
Severe pneumonia	20 (19.6)	22 (18.9)	16 (40.0)	21 (35.6)
Very severe illness	1 (1.0)	–	7 (17.5)	27 (45.8)

Values in parentheses denote percentages.

slums of Delhi and to determine the association between the indoor air pollution and ALRI. Limited data on ALRI are available from the underprivileged sections of the cities of India or elsewhere in the world. A total of 633 infants were followed for a maximum period of 15 weeks to determine incidence of ALRI among families using wood or kerosene for fuel. The study was restricted to the peak winter season for ALRI. In the present study, we have reported the number of episodes of ALRI each child suffered. To the best of our knowledge, no other study has performed analysis according to the number of episodes of ALRI each child suffered during the study period. The overall incidence rate of ALRI in this study population was found to be 3.9 episodes per 100 child weeks at risk (ranging from 6.3 to 1.6 in various fuel groups), whereas incidence rates reported in the BOSTID studies ranged from 0.2 to 8.1 new episodes of ARI per 100 child weeks at risk (*3*). This variation in the incidence rate could be because of variability in definitions used for diagnosis of ALRI. The list of signs observed by BOSTID for ALRI were one of the following: respiratory rate >50 per min, stridor, wheezing, convulsions, or chest indrawing; however, in the present study we followed WHO criteria for defining cases.

Age and sex distribution of ALRI cases and controls was comparable in both fuel groups and both study slums. The demographic data and risk factors including family size, parental education, occupation, number of siblings, and nutritional and immunization status among ALRI cases and controls in both study slums were comparable except that more primary educated mothers were found in the kerosene group in both slums (p<0.0000). In the kerosene group, there were more housewives than self-employed women in Kathputly Colony. Although the distribution of malnourished children was similar in all the groups, there were more severely malnourished infants in the wood group in Kusumpur Pahari. Risk factors such as young maternal age and literacy level of mother were not consistently associated with higher incidence rates in the present study; this is also reported in other studies (*3,15*). Moreover, we did not find any significant difference between the nutritional status of ALRI cases and controls. Therefore, our findings concur with BOSTID researchers, i.e., the impact of a low weight for age measure appears to be less important among children less than 18 months of age (*3*).

Despite comparable baseline demographic and risk factor characteristics, there was a marked difference in the number of cases of ALRI in Kusumpur Pahari (172) and Kathputly Colony (78). Further analysis revealed a longer duration of illness in Kusumpur Pahari. The illness of longer duration may actually have been a sequential infection, in addition to poor compliance with shorter or no intervening asymptomatic period. Moreover, better awareness, child rearing practices, and attitude towards health could also be responsible for lower incidence of ALRI in Kathputly Colony. There has been regular intervention by various voluntary health organizations at Kathputly Colony.

The majority of the cases were diagnosed as pneumonia in both groups and in both study slums. The percentage of bronchiolitis varied from 12 to 27%. About 1– 5% of the cases of bronchial asthma were included in ALRI cases by health workers because diagnosis was based on WHO criteria. The severity of illness was graded according to WHO criteria based on the information gathered by workers and examination by doctors. The number of cases of severe pneumonia varied from 18.1 to 40% in different groups. Although the total number of reported ALRI cases was lower in Kathputly Colony than in Kusumpur Pahari, greater severity of illness was reported in Kathputly Colony. Analysis of nutritional status was done at the completion of the study; therefore, this factor was not used to label children with severe malnutrition as having very severe illness. If malnutrition had been used as one of the criteria for severity of illness, a much higher number of ALRI cases could have been labeled as very severe illness in Kusumpur Pahari (mainly in the wood group), and it would have eliminated the present observed difference to a large extent. Moreover, kerosene stoves are a potential source of emission of harmful particulate matter (<2.5 μm), namely, polycyclic aromatic hydrocarbons, aliphatic hydrocarbons, nitrated hydrocarbons, etc. Smaller particulates emitted from kerosene are more harmful because they can be breathed more deeply into the lungs (*16*) and could lead to a greater severity of illness. The other reason for reporting greater severity in the kerosene group mainly at Kathputly Colony could be due to differences in assessment at the level of health workers and doctors. Although assessment of severity of illness, particularly lethargy and refusal of food, is subjective and could lead to a bias, an almost equal number of cases of ALRI was ascertained by health workers and doctors in their twice-weekly visits.

There was no significant difference in the number of ALRI cases in both fuel groups at Kusumpur Pahari whereas in Kathputly Colony, a highly polluted area, the difference between the two fuel groups was significant. This is perhaps because of the tendency of the ethnic groups to keep fires on for a very long time, and it was observed that the actual fraction of time spent near the fire by infants was longer in the kerosene users (*14*). Kerosene users tend to cook indoors and also keep their infants indoors. While an upward shift toward a cleaner fuel (kerosene) is postulated to reduce the exposure, this effect is perhaps being countered by the effect of shifting to a less ventilated environment and the effect of increased duration of exposure to indoor pollutants (*14*).

Fortunately, there were only three deaths related to ALRI in both fuel groups. The co-trimoxazole therapy, even in severe pneumonia and very severe illness, was found to be effective contrary to the recommendations in the WHO guidelines for ARI case management.

Conclusion

Although the study population appeared to be uniformly poverty stricken and had similar demographic characteristics, there were variations in the incidence rates within those studied, and the reasons for these differences need further elucidation. Apart from fuel type, other factors that may strongly influence incidence of ALRI are housing type, location of cooking, smoking habits, and cultural practices. Risk factors such as behavior, habits, and conditions that enhance transmission of agents or the susceptibility of the child should be studied in depth. The duration of illness and percentage of time the child is ill also should be analyzed for associated risk factors.

Prevention and minimization of ALRI during infancy may be accomplished partially by promoting maternal education and by improving socioeconomic development, all of which lead to better nutritional

and health status. Future strategies should include estimation of contaminants and changes in cooking practices and child rearing habits. Furthermore, informing parents about symptoms that indicate the severity of illness and the importance of early treatment at a health center might be valuable in this context.

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